

THE VASCULAR FLORA OF FIVE ROCK GLACIERS
IN THE SAN JUAN MOUNTAINS, COLORADO

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ABSTRACT

Rock glaciers are the most extensive Holocene glacial deposits in the Colorado Rocky Mountains. An inventory was taken of the vascular plant flora of five rock glacier complexes in alpine basins of the San Juan Mountains, Colorado. A flora of 89 species in 55 genera and 22 families is reported. Eight species were found only on the rock glaciers and not in the adjacent basins. Dominance within representative community types was analyzed.

Rock glaciers are the most common Holocene glacial deposits in the cirques of the Southern Rocky Mountains of Colorado (Meierding and Birkeland 1980). Many studies pertaining to the origin, age, morphology, ice composition, and movement of rock glaciers are found in the literature (Howe 1909, Capps 1910, Ives 1940, Wahrhaftig and Cox 1959, Outcalt and Benedict 1965, Barsch 1971, White 1971, White 1973, Ellis and Calkin 1979, Johnson 1983). Although there are some general references to the presence of vascular plants on rock glaciers in North America (Wahrhaftig and Cox 1959, White 1971, Madole 1972, White 1973, Carrara and Andrews 1976, Johnson 1983) no lists of species are given. The purpose of this study was to survey the vascular plant species present on five rock glaciers in the San Juan Mountains and to determine dominance within representative community types.

ROCK GLACIERS

Wahrhaftig and Cox (1959) describe rock glaciers as tongue-shaped or lobate masses of poorly sorted angular debris lying at the base of cliffs or talus slopes and ranging in size from a few hundred feet to over a mile in length, in the direction of flow, and a few hundred feet to nearly two miles in width, perpendicular to the direction of flow. Dimensions vary according to rock glacier type and topographic location. All rock glaciers have an ice component: either a central core of ice, superimposed by rock debris (ice-cored), or an interstitial matrix of ice (ice-cemented). The occurrence of rock glaciers also implies the occurrence of permafrost and a periglacial climate for maintenance of the landform (White 1981). The upper surface of most rock glaciers has a microrelief determined by a system of longitudinal and transverse ridges and furrows that give the impression of slow plastic or viscous flow (Wahrhaftig and Cox 1959).

There are two basic morphological types of rock glaciers. Tongue-shaped rock glaciers are usually ice-cored but may be ice-cemented (Madole 1972), have a greater length to width ratio, and originate in cirques where ice glaciers formerly occurred (White 1981) or in slight recesses on promontories or valley walls (Madole 1972). These forms have steep fronts of 38 to 50 degrees where basal shear resistance is great (White 1981).

Lobate rock glaciers are usually ice-cemented, have a greater width to length ratio, and form at the base of valley walls, usually as an extension of talus (White 1981). These forms have steep fronts of 40 to 55 degrees.

On the basis of movement rock glaciers may be categorized as active or inactive. Active tongue-shaped rock glaciers move 5-160 cm/yr depending upon size and slope angle whereas the lobate forms move substantially less, 1-6 cm/yr (White 1981). The front slopes of active rock glaciers are completely devoid of vegetation and form a sharp angle with the surface of the glacier. Inactive rock glaciers show no movement. The front slopes of the latter are covered with turf or lichens and are rounded at the junction of slope and surface (Wahrhaftig and Cox 1959).

In Colorado rock glaciers are reported for the Front Range, Mosquito Range, Sawatch Range, Elk Mountains, Sangre de Cristo Range, and San Juan Mountains. White (1973) identified 756 rock glaciers from aerial photos of the San Juan Mountains. Rock glaciers occur primarily above timberline.

STUDY AREAS

The San Juan Mountains are a discontinuous section of the Southern Rocky Mountains situated along the Continental Divide in southwestern Colorado. They are composed largely of Tertiary volcanic tuffs and lavas that lie unconformably over metamorphic, sedimentary and volcanic intrusive rocks of Precambrian age as well as sediments of Paleozoic, Mesozoic, and early Cenozoic age (Casadwall and Ohmoto 1977). All of the rock glaciers studied are tongue-shaped or tongue-lobate complexes and show evidence of movement; however, isolated, stabilized areas of fines, which support well-developed vascular plant communities are present to some extent on all but Gilpin rock glacier.

American Rock Glacier

American rock glacier (37° 54' N; 107° 31' W) is located approximately 15 km southwest of Lake City, Hinsdale Co. This massive, north-facing complex of tongue and lobate units has an elevational range of 4026-3770 m, from source to frontal slope (Fig. 1). The headwall source of the rock glacier debris consists of volcanic aphanitic andesite, welded tuff, and biotite-quartz latite (Lipman 1976).

Imogene Rock Glacier

Imogene rock glacier (37° 56' 40" N; 107° 44' W), a northeast-facing tongue rock glacier, is located approximately 11 km south-southwest of Ouray, Ouray Co. It has an elevational range of 3721-3464 m, from source to frontal slope. Headwall source material for this rock glacier consists of biotite-quartz latite and fluvial-banded flows of rhyodacitic composition (Burbank and Luedke 1966).

Gilpin Rock Glacier

Originating high on the flanks of Gilpin Peak, the Gilpin rock glacier (37° 59' 35" N; 107° 47' 30" W) is located approximately 14.5 km southwest of Ouray, Ouray Co. Although north-facing at its source, at 3965 m elevation, the rock glacier makes a 45° bend and becomes east-facing near its frontal slope, at 3721 m elevation. Headwall material is Gilpin Peak tuff consisting predominantly of quartz latite welded ash flow tuffs (Burbank and Luedke 1964).

Kendall Rock Glacier

Kendall Rock Glacier (37° 47' 05" N; 107° 37' 48" W) is located approximately 8 km southeast of Silverton, San Juan Co. North-northwest-facing at the source end, this rock glacier also makes a 45° bend to west-facing at the front terminus. The elevational range, lowest of all five rock glaciers, is 3782-3599 m, from source to frontal slope. The headwall source of the rock glacier debris consists of bedded tuff, agglomerate, and breccia of andesite and latite (Burbank et al. 1935).

Burns Rock Glacier

Located approximately 19 km northeast of Silverton, San Juan Co., Burns rock glacier (37° 53' 45" N; 107° 32' 15" W) is a complex of multiple lobate units that coalesce to form a short, west-facing tongue at its terminus. The elevational range, from source to frontal slope, is 3904-3697 m. Biotite-quartz latite and aphanitic andesite constitute the primary rock debris of the glacier.

METHODS

This study was conducted over five field seasons, 1981-1985. The surface and slopes of each of the five rock glaciers were systematically traversed in order to locate and flag potential vegetated areas for floristic inventory and community analysis. A total of 154 vascular plant communities and/or single species populations were analyzed. Dominance, when applicable, was determined according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg 1974). Nomenclature follows Kartesz and Kartesz (1980) with alternate names used by Weber (1984) added in parentheses. Voucher specimens are deposited in COLO and CU-Denver.

RESULTS AND DISCUSSION

Flora

The alpine flora present on five rock glaciers in the San Juan

Mountains consists of 86 species representing 52 genera in 19 families of angiosperms, one species of gymnosperm, and two species in two genera of pteridophytes. The Asteraceae, Brassicaceae, and Cyperaceae are the leading families contributing 21%, 13%, and 8% of the taxa, respectively. The Poaceae, which is usually among the three leading families in most Colorado tundra floras (Michener 1964, Komarkova 1976, Webber et al. 1976, Hartman and Rottman 1985), is replaced by the Brassicaceae in this study. Eight species found on the rock glaciers were not found in the adjacent basins. These include: Agrostis filiculmis (Agrostis idahoensis), Arabis lemmonii (Boechnera lemmonii), Draba incerta, Erigeron vagus, Penstemon harbourii, Phlox caespitosa ssp. pulvinata (Phlox pulvinata), Senecio porteri, (Ligularia porteri), and Stellaria irrigua.

Vascular plant species on the rock glaciers studied occur either in highly localized communities on stable sites or as isolated populations of single species in unstable areas. The community types represented are fellfield, dry meadow, moist meadow, and krummholz. Single species populations are characteristic of rock crevices and rock debris habitats.

Rock Debris

Because the rock glacier surface and slopes are formed of rock debris from the headwall or source area, rock debris is the most abundant habitat found on the five rock glaciers studied. The debris ranges in size from large boulders, up to two m in diameter, to cobbles and fines. There are limited areas in rock interstices and at the base of boulders on the rock glacier that have a sufficient accumulation of fines to support vascular plant species. These areas become available for colonization when the surficial deposits of rock material move down slope exposing the finer material present in the lower strata. Creeping-stemmed species such as Erigeron vagus, Penstemon harbourii, Senecio porteri (Ligularia porteri), and Stellaria irrigua are occasionally found among the rock debris. Many of the rock debris habitats, especially rock interstices, support only single species populations. Where fines and soil accumulation occur in flat areas at the base of boulders, communities of low richness and no dominance are found. Some of the common species that may occur singly or in some combination in rock debris habitats are Androsace septentrionalis, Aquilegia coerulea, Cerastium earlei (Cerastium beeringianum ssp. earlei), Draba crassifolia, Festuca brachyphylla, Potentilla diversifolia, Saxifraga debilis (Saxifraga hyperborea ssp. debilis), Senecio werneriiifolius (Packera werneriiifolia), Sibbaldia procumbens, Smelowskia calycina, and Trisetum spicatum.

Rock Crevice

The rock crevice habitat includes soil-filled crevices on solitary boulders. These crevices are formed by jointing of the rock material. Younkin (1970) reports that the thin soils in the rock crevices are often composed of organic matter and that the orientation of the crevices on the rock substrate determines the insolation factors of the particular habitat. On all of the rock

glaciers the rock habitat is usually represented by a single species population. Although species may occur together in this habitat, there are no dominants. The species most frequently encountered are Carex elynoides, Claytonia megarhiza, Erysimum capitatum var. amoenum (Erysimum capitatum, alpine ecotype), Festuca brachyphylla, Polemonium viscosum, Sagina saginoides, Saxifraga rhomboidea (Micranthes rhomboidea), Senecio amplexans var. amplexans (Ligularia amplexans), Senecio amplexans var. holmii (Ligularia holmii), and Smelowskia calycina.

Fellfield

Fellfield community sites are characterized by a high proportion of weathered rock material (up to 80%), coarse-textured soils, and little organic material. They occur on exposed, windswept ridges with little or no snow cover, thus exposing the plants and soil to severe desiccation. The highest richness of species on rock glaciers occurs in this community. The dominants include Carex elynoides, Chionophila jamesii, Selaginella densa, Senecio werneriiifolius (Packera werneriiifolia), Silene acaulis var. subacaulis (Silene acaulis ssp. subacaulis), and Trisetum spicatum.

Dry Meadow

This community type occurs in stable areas on convex slopes that experience early snowmelt. Although the substrate includes some rock fragments, soil accumulation is sufficient to permit a better development of vegetation than the fellfield. The most frequent dominants are Carex elynoides, Geum rossii var. turbinatum (Acomastylis rossii ssp. turbinata), Phlox caespitosa ssp. pulvinata (Phlox pulvinata), Saxifraga bronchialis ssp. austromontana (Ciliaria austromontana), and Selaginella densa.

Moist Meadow

In striking contrast to the moist meadow communities in the adjacent basins (Hartman and Rottman 1985), the rock glacier moist meadows are low in species richness and minimal in occurrence, being found only on Imogene rock glacier. They occur in depressions where snow accumulation is greater and release is later at or near the base of a highly stable longitudinal lobe. The dominant species are Salix reticulata ssp. nivalis and Sibbaldia procumbens.

Krummholz

Wardle (1974) defines timberline as the ecotone between the subalpine zone, including both forest and ecotonal krummholz, and the alpine zone of low growing vegetation. He describes krummholz as a modification of the normal upright conifer growth form caused by the severity of the habitat. In the most severe sites krummholz conifers are reduced cushions of contorted stems that are shorn off level with the surface of the winter snowpack. In less severe sites, erect stems with branches only on their leeward sides rise above the cushion to produce flagged krummholz. Kendall rock glacier is the only rock glacier on which krummholz, of the mixed cushion and flag types, occurs at approximately 3652 m elevation. Picea engelmannii

is the only gymnosperm species represented in four scattered communities. The understory dominants include Carex elynoides and Salix reticulata ssp. nivalis.

INVENTORY OF VASCULAR PLANT SPECIES ON ROCK GLACIERS
SAN JUAN MOUNTAINS, COLORADO

Achillea millefolium L. var. lanulosa (Nutt.) Piper
(Achillea lanulosa Nutt.)

krummholz

Agropyron scribneri Vasey
(Elymus scribneri [Vasey] Jones)

rock debris, fellfield

Agrostis filiculmis M.E. Jones
(Agrostis idahoensis Nash)

dry meadow

Androsace septentrionalis L.
rock debris, fellfield, dry meadow

Angelica grayi Coult. & Rose
rock debris, fellfield, dry meadow

Antennaria alpina (L.) Gaertn
(Antennaria media Greene)

rock debris, fellfield

Antennaria microphylla Rydb.
fellfield, dry meadow, moist meadow, krummholz

Aquilegia coerulea James
rock debris, fellfield, dry meadow, moist meadow, krummholz

Arabis divaricarpa A. Nels.
(Boechera divaricarpa [A. Nels.] Love & Love)
rock debris

Arabis drummondii Gray
(Boechera drummondii [A. Gray] Love & Love)
krummholz

Arabis lemmonii S. Wats.
(Boechera lemmonii [S. Wats.] W. Weber)
rock debris

Arnica mollis Hook.
rock debris

Artemisia scopulorum Gray
fellfield, dry meadow, moist meadow, krummholz

Besseyia alpina (Gray) Rydb.
rock debris, fellfield

Carex albonigra Mackenzie
rock debris, fellfield, moist meadow

Carex arapahoensis Clokey
rock debris

Carex elynoides Holm
rock debris, rock crevice, fellfield, dry meadow, krummholz

Carex heteroneura W. Boott var. chalciolepis (Holm) F.J. Herm.
(Carex chalciolepis Holm)
rock debris, fellfield, dry meadow, moist meadow, krummholz

Carex phaeocephala Piper
rock debris, fellfield, dry meadow, krummholz

- Carex pseudoscirpoidea Rydb.
rock debris
- Carex pyrenaica Wahlenb.
(Carex crandallii Gand.)
rock debris
- Castilleja haydenii (Gray) Cockerell
rock debris, krummholz
- Cerastium earlei Rydb.
(Cerastium beeringianum C. & S. ssp. earlei [Rydb.] Hulten)
rock debris, fellfield
- Chionophila jamesii Benth.
rock debris, fellfield
- Claytonia megarhiza (Gray) Parry ex S. Wats.
rock debris, rock crevice, fellfield, krummholz
- Cystopteris fragilis (L.) Bernh.
krummholz
- Draba aurea Vahl
dry meadow
- Draba crassa Rydb.
rock debris
- Draba crassifolia Graham
rock debris, fellfield
- Draba incerta Payson
rock debris
- Erigeron grandiflorus Hook.
moist meadow, krummholz
- Erigeron melanocephalus A. Nels.
rock debris, dry meadow
- Erigeron pinnatisectus (Gray) A. Nels.
rock debris, rock crevice, fellfield, dry meadow, krummholz
- Erigeron simplex Greene
rock debris, fellfield, dry meadow, krummholz
- Erigeron vagus Payson
rock debris
- Erysimum capitatum (Dougl.) Greene var. amoenum (Greene) R.J. Davis
(Erysimum capitatum [Dougl.] Greene, alpine ecotype)
rock debris, rock crevice, fellfield, dry meadow
- Festuca brachyphylla Schultes
rock debris, rock crevice, fellfield, dry meadow, krummholz
- Geum rossii (R. Br.) Ser. var. turbinatum (Rydb.) C.L. Hitchc.
(Acomastylis rossii [R. Br.] Greene ssp. turbinata [Rydb.] W. Weber)
rock debris, fellfield, dry meadow, moist meadow, krummholz
- Hymenoxys grandiflora (Torr. & Gray ex Gray) Parker
(Rydbergia grandiflora [T. & G.] Greene)
krummholz
- Lloydia serotina (L.) Salis. ex Reichenb.
rock debris, fellfield, dry meadow
- Luzula spicata (L.) DC.
rock debris, dry meadow, moist meadow, krummholz
- Minuartia obtusiloba (Rydb.) House
(Lidia biflora [L.] Love & Love)
fellfield, dry meadow, krummholz

- Minuartia rubella (Wahlenb.) Hiern
(Tryphane rubella [Wahlenb.] Reichenb.)
fellfield
- Oreoxis alpina (Gray) Coult. & Rose
dry meadow, moist meadow
- Oreoxis bakeri Coult. & Rose
fellfield, dry meadow, moist meadow, krummholz
- Oxyria digyna (L.) Hill
rock debris, fellfield
- Penstemon harbouirii Gray
rock debris, fellfield
- Penstemon whippleanus Gray
krummholz
- Phacelia sericea Hook.
rock debris, fellfield
- Phlox caespitosa Nutt. ssp. pulvinata Wherry
(Phlox pulvinata Wherry)
rock debris, dry meadow, moist meadow
- Picea engelmannii Parry ex Engelm.
krummholz
- Poa alpina L.
rock debris, fellfield, dry meadow
- Poa rupicola Nash ex Rydb.
(Poa glauca Vahl)
rock debris, fellfield, dry meadow, krummholz
- Polemonium viscosum Nutt.
rock debris, rock crevice, fellfield, krummholz
- Polygonum bistortoides Pursh
(Bistorta bistortoides [Pursh] Small)
fellfield
- Polygonum viviparum L.
(Bistorta vivipara [L.] S. Gray)
rock debris
- Potentilla diversifolia Lehm.
rock debris, fellfield, dry meadow, krummholz
- Ranunculus macauleyi Gray
rock debris, fellfield, dry meadow, moist meadow
- Sagina saginoides (L.) Karst
rock debris, rock crevice
- Salix glauca L.
fellfield, dry meadow, krummholz
- Salix reticulata Hook. ssp. nivalis (Hook.) Love, Love & Kapoor
fellfield, dry meadow, moist meadow, krummholz
- Sambucus racemosa L. ssp. pubens (Michx.) House
rock debris
- Saxifraga adscendens L. ssp. oregonensis (Raf.) Bacig.
(Muscaria adscendens [L.] Small)
fellfield
- Saxifraga bronchialis L. ssp. austromontana (Wieg.) Piper
(Ciliaria austromontana [Wieg.] W. Weber)
rock debris, fellfield, dry meadow, krummholz
- Saxifraga debilis Engelm. ex Gray

(Saxifraga hyperborea R. Br. ssp. debilis [Engelm] Love, Love & Kapoor)

rock debris, fellfield, dry meadow

Saxifraga flagellaris (Sternb.) Willd. ssp. platysepala (Trautv.) Porsild

(Hirculus platysepalus [Trautv.] W. Weber ssp. crandalli [Gand.] W. Weber)

rock debris, fellfield

Saxifraga rhomboidea Greene

(Micranthes rhomboidea [Greene] Small)

rock debris, rock crevice, fellfield, dry meadow, moist meadow, krummholz

Sedum integrifolium (Raf.) A. Nels. ex Coult. & A. Nels.

(Rhodiola integrifolia Raf.)

rock debris, fellfield, dry meadow

Sedum lanceolatum Torr.

(Amerosedum lanceolatum [Torr.] Love & Love)

fellfield, dry meadow

Selaginella densa Rydb.

rock debris, rock crevice, fellfield, dry meadow, moist meadow

Senecio amplexans Gray var. amplexans

(Ligularia amplexans [A. Gray] W. Weber)

rock debris

Senecio amplexans Gray var. holmii (Greene) Harrington

(Ligularia holmii [Greene] W. Weber)

rock debris, fellfield, dry meadow, krummholz

Senecio porteri Greene

(Ligularia porteri [Greene] W. Weber)

rock debris

Senecio soldanella Gray

(Ligularia soldanella [Gray] W. Weber)

rock debris, fellfield

Senecio werneriiifolius Gray

(Packera werneriiifolia [Gray] Weber & Love)

rock debris, fellfield, dry meadow, moist meadow, krummholz

Sibbaldia procumbens L.

rock debris, rock crevice, fellfield, dry meadow, moist meadow

Silene acaulis (L.) Jacq. var. subacaulis (F.N. Williams) C.L.

Hitchc. & Maguire

(Silene acaulis (L.) Jacq. ssp. subacaulescens [F.N. Williams])

Hitchc. & Maguire)

rock debris, fellfield, dry meadow, moist meadow

Smelowskia calycina (Steph.) C.A. Mey. ex Ledeb.

rock debris, rock crevice, fellfield, dry meadow

Stellaria irrigua Bunge

rock debris

Stellaria umbellata Turcz. ex Kar. & Kir.

rock debris, fellfield

Taraxacum ceratophorum (Ledeb.) DC.

rock debris, dry meadow

Taraxacum lyratum (Ledeb.) DC.

fellfield

- Thlaspi montanum L.
(Noccaea montana [L.] F.K. Meyer)
rock debris, dry meadow
- Trifolium attenuatum Torr. & Gray
rock debris
- Trifolium nanum Torr.
rock debris, fellfield, dry meadow
- Trisetum spicatum (L.) Richter
rock debris, fellfield, dry meadow, krummholz
- Vaccinium scoparium Leib.
moist meadow
- Valeriana capitata Pallas ex Link
moist meadow
- Zigadenus elegans Pursh
(Anticlea elegans [Pursh] Rydb.)
fellfield, dry meadow

ACKNOWLEDGMENTS

We thank Barbara A. Siems and Diane C. Wilson for field assistance on Gilpin, Imogene, and Kendall rock glaciers during the 1985 season.

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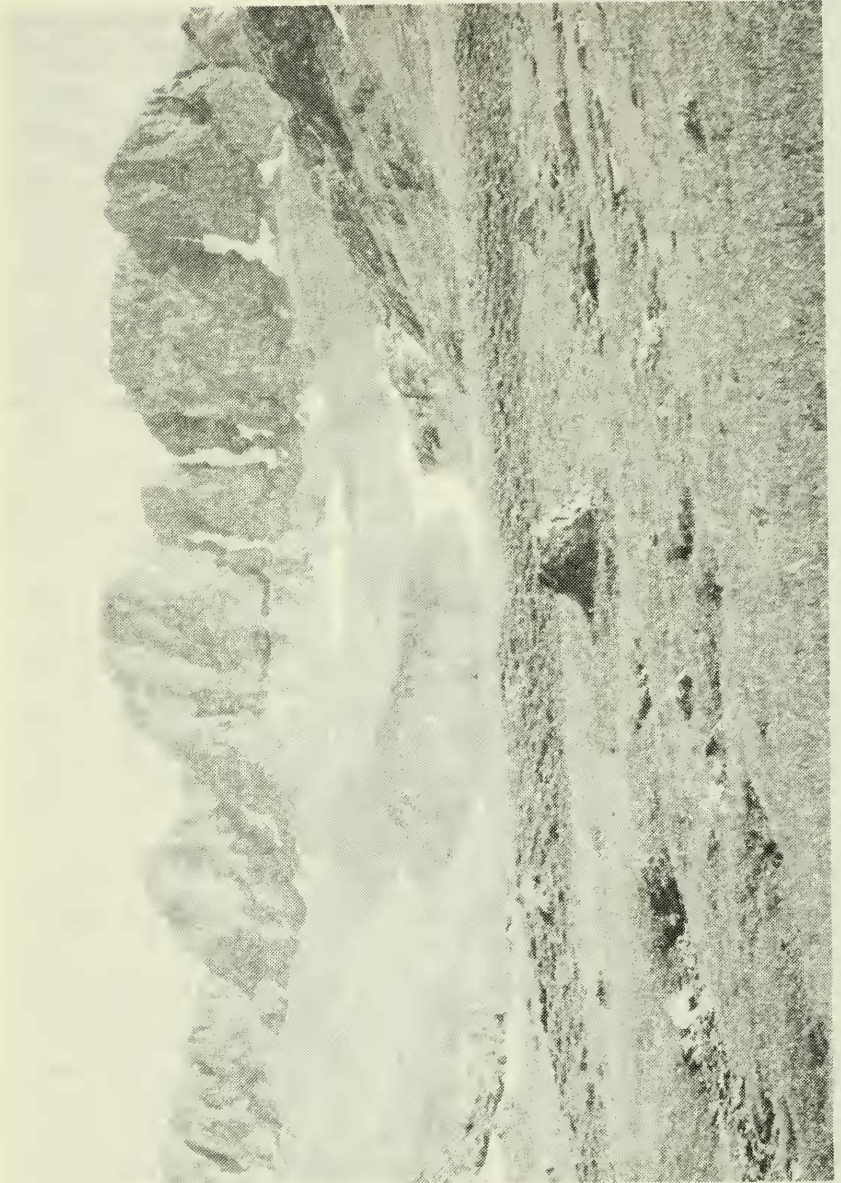


Fig. 1 American rock glacier and headwall, American Basin. East and west lobate units in background; coalesced tongue-shaped unit in center.